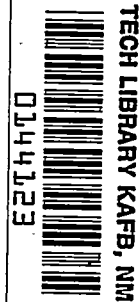


Reg # 16280

270

Copy  
RM L55E06

NACA RM L55E06



NACA

# RESEARCH MEMORANDUM

AN INVESTIGATION OF JET EFFECTS ON ADJACENT SURFACES

By Walter E. Bressette and Maxime A. Faget

Langley Aeronautical Laboratory

Langley Field, Va. *Classified*

Classification cancelled (or changed to) *Declassified*

By Authority of *2-10-53 Tech Pub. Announcement File*  
(OFFICER AUTHORIZED TO CHANGE)

By *32 May 57*  
NAME AND

*W. E. Bressette*  
GRADE OF OFFICER MAKING CHANGE)

*3 Apr 61*  
DATE

NATIONAL ADVISORY COMMITTEE  
FOR AERONAUTICS

WASHINGTON

June 28, 1955



0144123

## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## RESEARCH MEMORANDUM

## AN INVESTIGATION OF JET EFFECTS ON ADJACENT SURFACES

By Walter E. Bressette and Maxime A. Faget

## SUMMARY

The steady pressure loads as well as the temperature change on adjacent surfaces due to the presence of a propulsive jet at subsonic speeds is shown to be insignificant. Whereas at supersonic speeds the temperature effect might be expected to remain insignificant, the steady pressure loads were shown to increase greatly on surfaces downstream of the propulsive jet exit.

## INTRODUCTION

In the past few years an investigation has taken place in the preflight blowdown tunnel at the Langley Aeronautical Laboratory to determine the jet effects on surfaces located in the near vicinity and downstream of a propulsive jet exit. The purpose of this paper is to supplement information already published at Mach number 2.00 with information obtained at other Mach numbers. The jet effects discussed are the steady pressure loads produced on a flat-plate wing due to the presence of a propulsive jet, the heating of the wing surface by the propulsive jet, and the fluctuating pressure frequency spectra superimposed on the wing steady pressures from the propulsive jet.

## SYMBOLS

$D_j$	diameter of sonic exit
$D_{j*}$	diameter of sonic throat
$\Delta C_N$	incremental normal-force coefficient, $\frac{\Delta N_{total}}{qS_{j*}}$
$H_j$	total pressure at exit of nacelle
$M_o$	free-stream Mach number

~~CONFIDENTIAL~~~~HAB055 3094S~~

$\Delta N$	incremental normal force, $(\text{Normal force})_{\text{jet on}} - (\text{Normal force})_{\text{jet off}}$
$P$	wing pressure coefficient, $\frac{P_w - P_o}{q}$
$\Delta P$	incremental pressure coefficient, $P_{\text{jet on}} - P_{\text{jet off}}$
$P_w$	wing static pressure
$P_o$	free-stream static pressure
$\bar{p}$	overall acoustic pressure fluctuations
$q$	free-stream dynamic pressure
$S_{j*}$	area of sonic throat
$T_{\text{WING}}$	static temperature on wing
$T_{s_o}$	free-stream stagnation temperature
$V_e$	velocity at the nacelle exit
$x$	chordwise distance on wing from nacelle exit (downstream positive)
$y$	spanwise distance on wing from nacelle center line

#### APPARATUS

Presented in figure 1 is a three-dimensional sketch of the test setup showing a small-scale nacelle mounted below a flat-plate wing at the exit of the preflight blowdown tunnel. The general airplane configurations in the figure are the type of airplane configurations that this test setup would apply to. The shaded areas on the configurations are the areas most likely to experience the type of jet effects that are discussed in this paper.

Presented in figure 2 is a side view of the test setup showing the small-scale nacelle, having a  $5^\circ$  boattail angle, mounted at  $3.35D_j$  below the flat-plate wing at the exit of the preflight blowdown tunnel. Although more than one vertical position was tested in this investigation,

a vertical position of  $3.35D_j$  was selected for this paper in order to correlate the additional data with an exact position that has already been published at a Mach number of 2.00 (ref. 1). The nacelle at this position was tested with two types of exit nozzles, a convergent nozzle called a sonic exit and a convergent-divergent nozzle called a super-sonic exit, both having the same size sonic throat.

#### INSTRUMENTATION

Figure 3 shows the location from the nacelle exit of 47 static-pressure orifices on the wing as well as the high-frequency pressure pickup and a thermocouple plate with 24 thermocouples that was installed in a similar wing.

#### RESULTS AND DISCUSSION

The pressure field on the wing with nacelle jet off is presented in figure 4 and shows the nacelle wake which is responsible for the formation in the free-stream flow of a jet-off trailing wake shock wave. In the jet-off operation, the pressure is negative downstream of the nacelle exit because of the presence of the nacelle boattail angle and rises to a positive pressure further downstream because of the intersection on the flat-plate wing of the jet-off trailing wake shock wave.

In figure 5 is presented a typical nacelle jet-on pressure field on the wing showing the propulsive jet issuing from the exit of the nacelle and flowing downstream below the flat-plate wing. In the jet-on operation, a shock wave (called the primary shock wave) forms at the exit of the nacelle, and the impingement on the wing of this shock wave is responsible for the formation of the first positive pressure in the field. This positive pressure gradually falls off in pressure until a second positive pressure rise occurs, which is less intense than the first one. This second positive pressure rise is caused by the intersection on the wing of a second jet-on shock wave (called the secondary shock wave) that is formed in the propulsive jet wake downstream of the nacelle exit.

Presented in figure 6 is the axial pressure distribution downstream of the nacelle exit for both jet on and jet off at the same value of  $H_j/p_o$  for  $M_o$  of 1.40, 1.80, and 2.00. The first positive pressure rise on the wing with jet on moves farther to the rear of the nacelle exit with an increase in  $M_o$ . This effect is the result of decreasing the primary shock-wave angle when  $M_o$  is increased at a constant value of  $H_j/p_o$ .

~~CONFIDENTIAL~~  
HAB855 30948

Because all pressures on the wing vary with nacelle-exit jet off depending upon the general configuration of the nacelle, the pressure on the wing also varies with the nacelle jet on; but the increment of pressure between jet on and jet off, or the pressure on the wing due to the presence of the propulsive jet, should remain the same. Therefore, all discussion of pressures and loads that follow in this paper will be in the form of incremental pressures and incremental loads.

Shown in figure 7 is the incremental pressure field due to the nacelle jet wake for a sonic exit and a supersonic exit at the same  $H_j/p_o$ .

When jet-on and jet-off wing pressure data were combined to form the incremental pressure data, positive incremental pressure resulted immediately behind the intersection on the wing of the primary shock wave. This positive incremental pressure gradually decreased until it became negative in the vicinity of the intersection on the wing of the jet-off trailing wake shock and it remained negative to the end of the wing.

The primary shock-wave angle was lower in angle for the supersonic exit than it was for the sonic exit. Therefore, the positive pressure behind the shock wave as well as the area upon which it acts was reduced.

From an integration of these chordwise incremental pressure profiles, the spanwise incremental wing loading can be obtained. In figure 8 the relative spanwise incremental wing loading is presented for a sonic exit with  $H_j/p_o = 6$  for  $M_o$  of 1.40, 1.80, and 2.00.

With an increase in  $M_o$ , the spanwise distance from the nacelle-exit center line upon which the loads act is decreased. This is a result of decreasing the primary shock-wave angle by increasing  $M_o$ . Also shown is a subsonic test made at  $M_o = 0.80$  and  $H_j/p_o = 3.37$ . From this test, slight negative pressures on the wing were obtained. From an integration of the spanwise wing loading,  $\Delta C_N$  can be obtained.

Figure 9 presents the variation of  $\Delta C_N$  with  $H_j/p_o$  for a nacelle sonic exit at  $M_o$  of 1.40, 1.80, 2.00, and 0.80. The value of  $\Delta C_N$  at a constant value of  $H_j/p_o$  in the supersonic range is decreased with an increase in  $M_o$ ; but with the  $\Delta C_N$  curves tending to increase with an increase in  $H_j/p_o$  and with present-day turbojet engines indicating that a maximum value of  $H_j/p_o$  of 5 will be produced at  $M_o = 1.40$ , of 9 at  $M_o = 1.80$ , and of 10 at  $M_o = 2.00$ , then a nearly constant  $\Delta C_N$  is indicated from this flat-plate-wing analysis for maximum cruising operation.

~~CONFIDENTIAL~~

In figure 10 is presented the variation of  $\Delta C_N$  with  $H_j/p_o$  for a nacelle sonic exit and a nacelle supersonic exit at  $M_o = 1.40$ . The value of  $\Delta C_N$  was reduced at all  $H_j/p_o$  tested by using a nacelle supersonic exit.

Presented in figure 11 is the variation of the ratio of  $\Delta N$  to thrust with  $H_j/p_o$  for a nacelle sonic exit at all free-stream supersonic Mach numbers tested. As can be seen in the figure there is little difference in the ratio of  $\Delta N$  to thrust with a decrease in  $M_o$ , and a mean lower value of 0.6 was obtained at a nacelle-exit pressure ratio of 7. Although  $\Delta N$  increased with an increase in  $H_j/p_o$ , this figure shows that it did not increase as rapidly as the thrust did.

In figure 12 is presented the axial temperature distribution downstream of the nacelle exit at  $M_o = 0.80$  with nacelle jet on and nacelle jet off. The ordinate of the curves is the ratio of the temperature as measured on the wing during steady-state conditions divided by the free-stream stagnation temperature. A nacelle jet temperature of  $1,500^\circ \text{F}$  with  $H_j/p_o = 4$  was obtained for the jet-on tests by burning hydrogen in air at a low fuel-air ratio. The broken lines show the temperature distribution with nacelle jet off. The solid lines show the temperature distribution with the nacelle jet on at two vertical positions from the wing, the higher one being at  $1.7D_j$  from the wing and the lower one being at  $3.35D_j$  from the wing. The maximum difference between jet-off temperature and jet-on temperature is less than  $10^\circ \text{F}$  indicating very little heating due to the presence of the propulsive jet. It should be noted that the hot exhaust gas in the propulsive jet wake did not penetrate the free-stream flow to the wing surface in a distance of  $6D_j$  downstream of the nacelle exit.

Presented in figure 13 is the frequency spectra of  $\bar{p}$  that were obtained at a point immediately behind the intersection on the wing of the primary shock wave, whereas  $H_j/p_o$  was varied from 7 to 2 at  $M_o = 1.80$  for a nacelle sonic exit and a nacelle supersonic exit. These data were preliminary and were obtained with a specially designed pickup using a small-scale nacelle having a sonic throat of 0.72 inch in diameter. These data show that  $\bar{p}$  is greater for the supersonic exit than it was for the sonic exit. Also, the range of pressures is essentially in agreement with that obtained by Lassiter and Hubbard (ref. 2), for a sonic jet with no free-stream flow.

~~CONFIDENTIAL~~

~~WADD 55-3094S~~

## CONCLUDING REMARKS

The steady pressure loads as well as the temperature change on adjacent surfaces due to the presence of a propulsive jet at subsonic speeds is shown to be insignificant. Whereas at supersonic speeds the temperature effect might be expected to remain insignificant, the steady pressure loads were shown to increase greatly on surfaces downstream of the propulsive jet exit.

Langley Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va., April 20, 1955.

## REFERENCES

1. Bressette, Walter E.: Investigation of the Jet Effects on a Flat Surface Downstream of the Exit of a Simulated Turbojet Nacelle at a Free-Stream Mach Number of 2.02. NACA RM L54E05a, 1954.
2. Lassiter, Leslie W., and Hubbard, Harvey H.: The Near Noise Field of Static Jets and Some Model Studies of Devices for Noise Reduction. NACA TN 3187, 1954.

~~CONFIDENTIAL~~

## APPLICATION OF JET EFFECTS

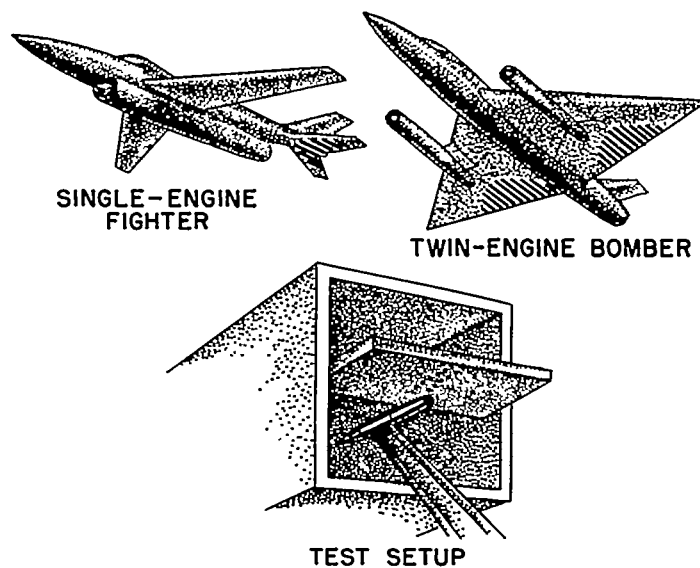


Figure 1

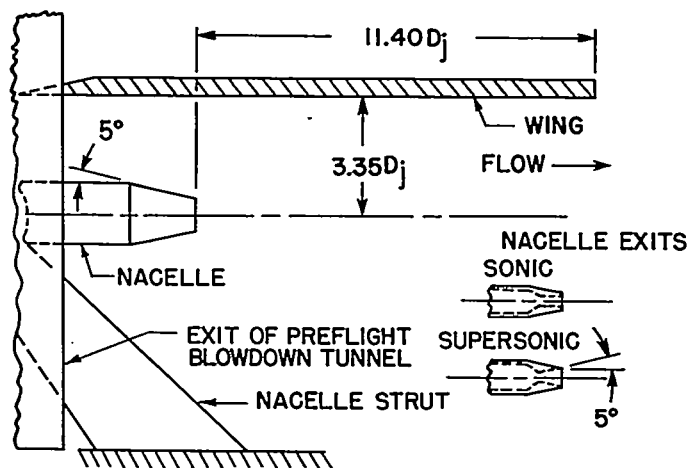
TEST SETUP  
(SIDE VIEW)

Figure 2

~~CONFIDENTIAL~~



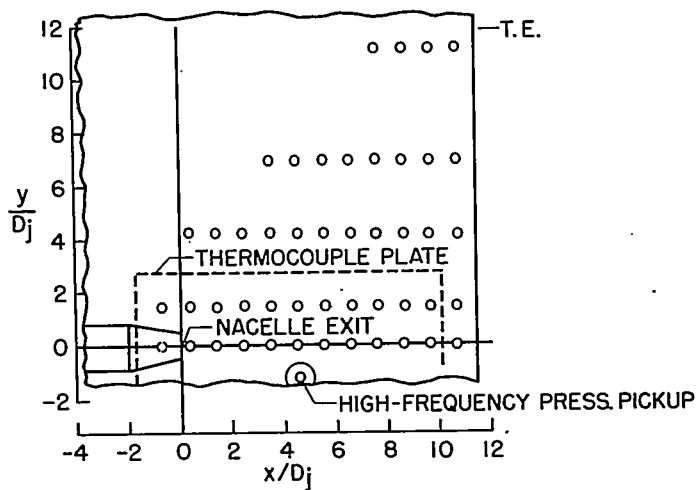
LOCATION OF WING INSTRUMENTATION  
(BOTTOM VIEW)

Figure 3

## PRESSURE FIELD ON WING WITH JET OFF

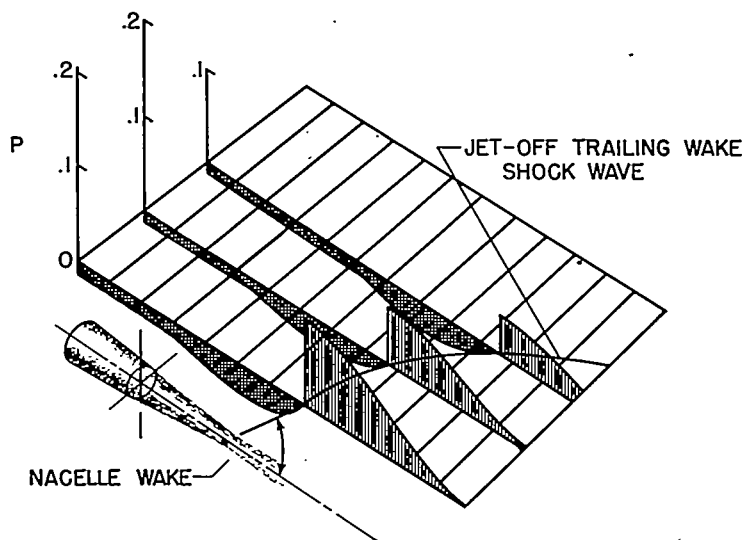


Figure 4

~~CONFIDENTIAL~~

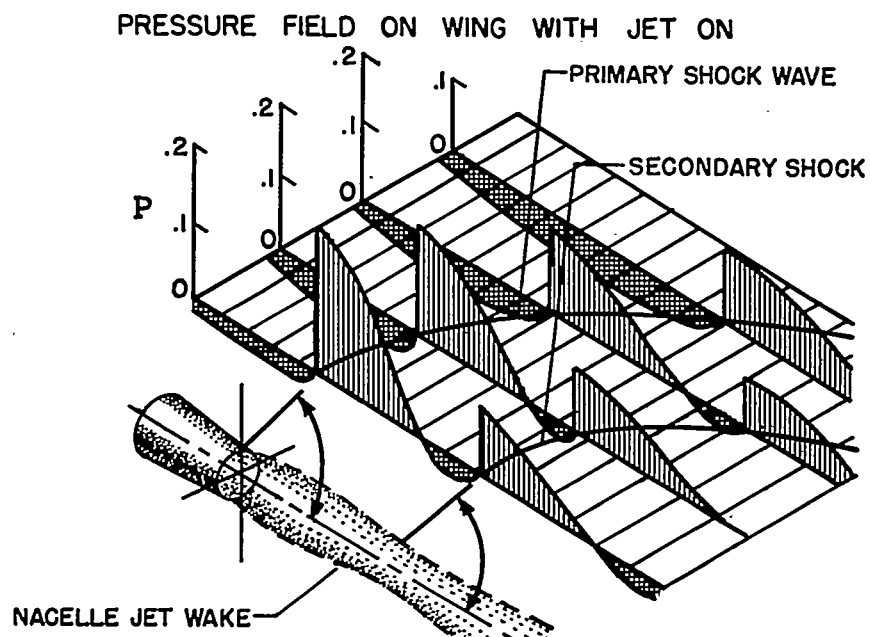


Figure 5

AXIAL PRESSURE DISTRIBUTION  
DOWNSTREAM OF NACELLE EXIT

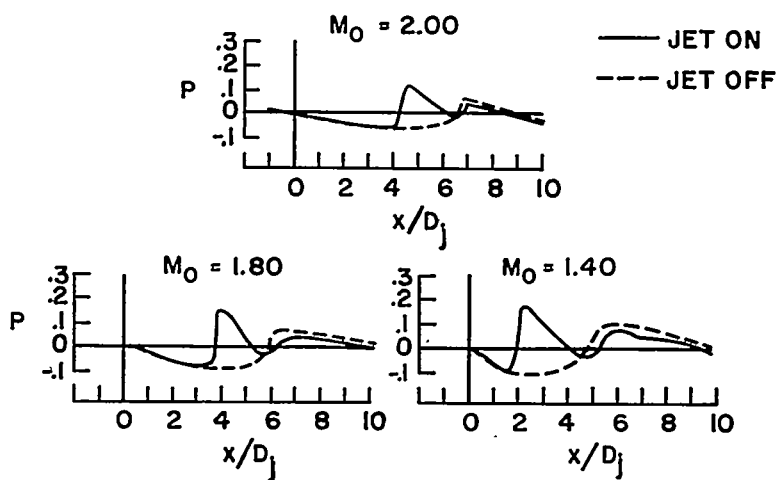


Figure 6

## PRESSURE FIELD ON WING DUE TO NACELLE JET WAKE

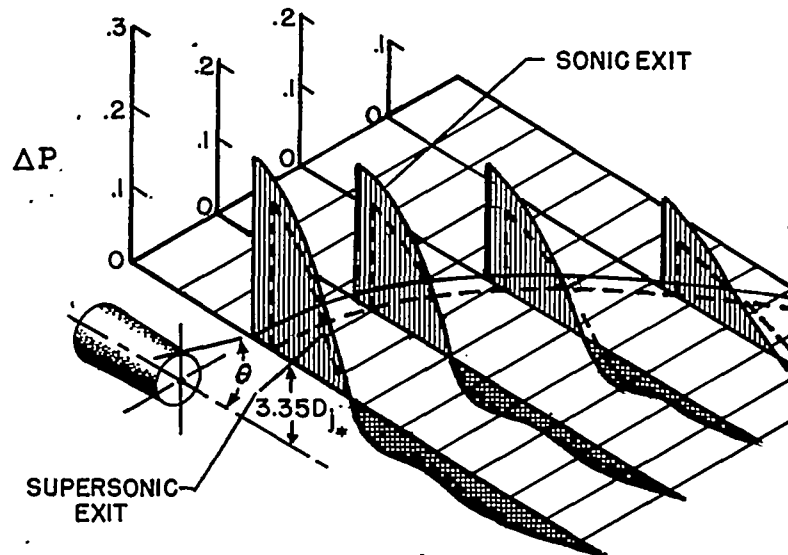


Figure 7

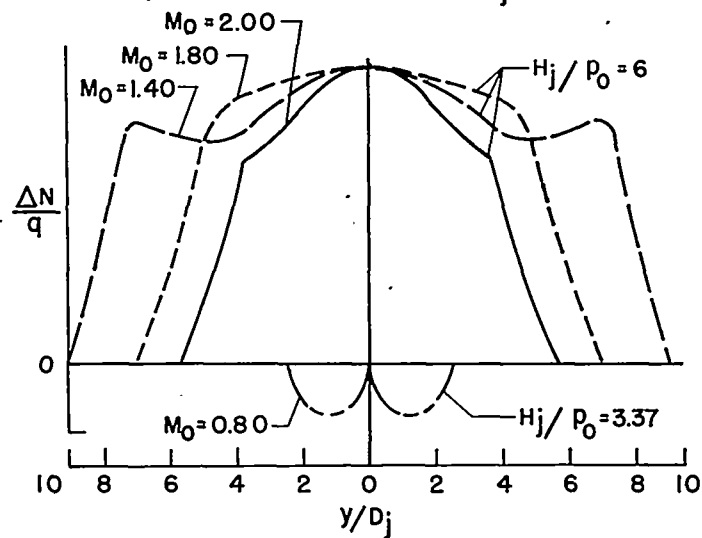
RELATIVE SPANWISE WING LOADING  
SONIC EXIT; WING TRAILING EDGE  $9D_j$  DOWNSTREAM

Figure 8

VARIATION OF NORMAL-FORCE COEFFICIENT  
SONIC EXIT; WING TRAILING EDGE  $9D_j$  DOWNSTREAM

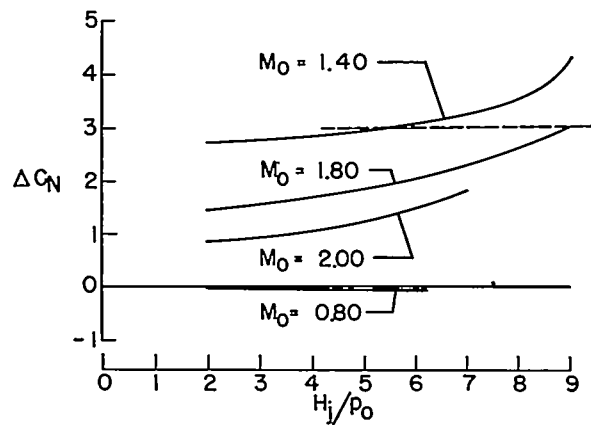


Figure 9

NORMAL-FORCE COEFFICIENT FOR  
SONIC AND SUPERSONIC NACELLE EXITS  
 $M_0 = 1.40$

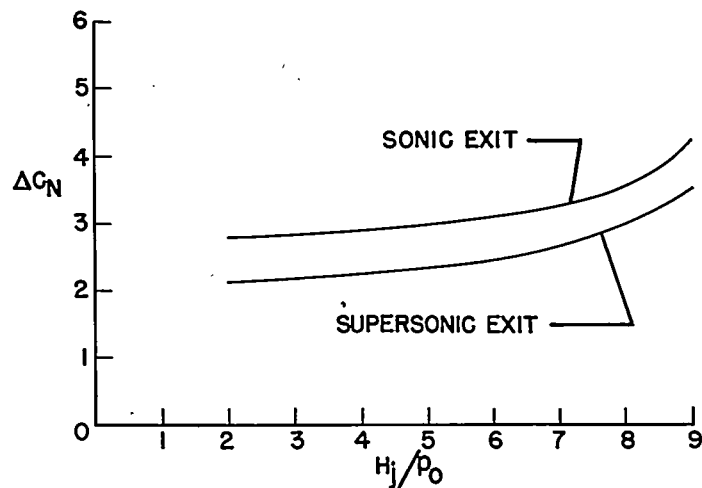


Figure 10

CONFIDENTIAL

VARIATION OF RATIO OF NORMAL FORCE TO  
THRUST WITH PRESSURE RATIO  
SONIC EXIT

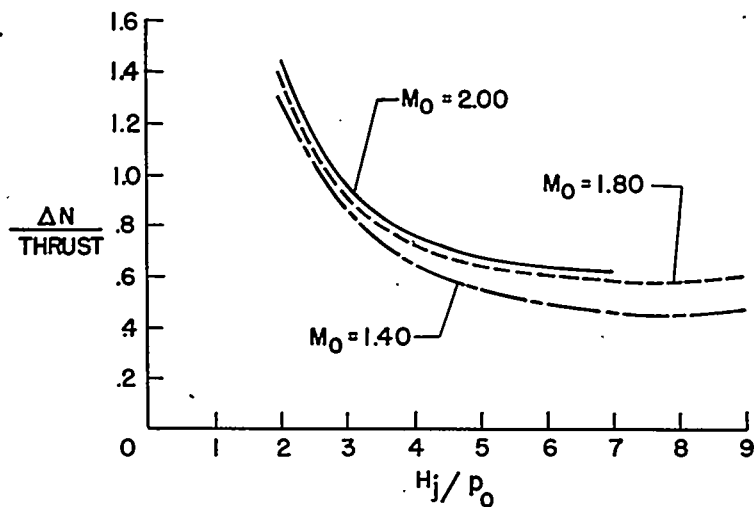


Figure 11

AXIAL TEMPERATURE DISTRIBUTION DOWNSTREAM  
OF NACELLE EXIT

$M_0 = 0.80$ ; JET TEMPERATURE,  $1500^\circ\text{F}$ ;  $H_j/p_0 = 4$

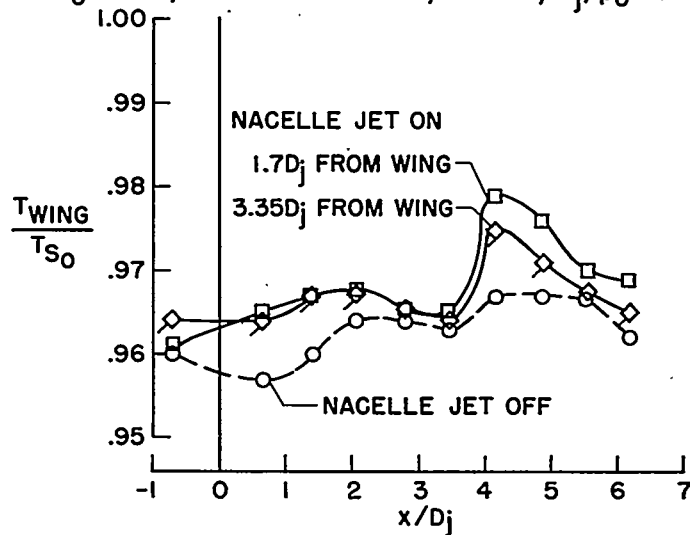


Figure 12

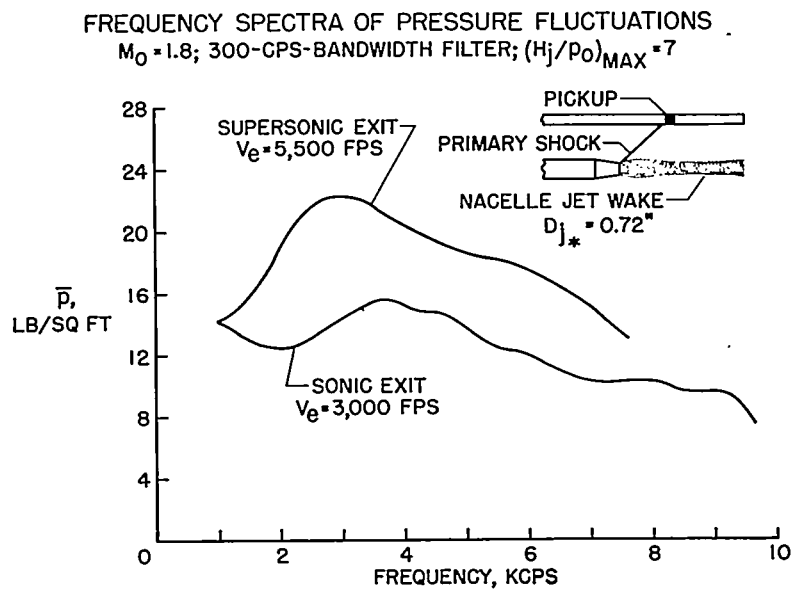


Figure 13